

What is claimed is:

1 1. A method of imaging an artery in a patient using
2 magnetic resonance imaging, comprising,
3 collecting image data; and
4 administering magnetic resonance contrast agent to the
5 patient prior to collecting image data, by intravenous infusion,
6 at a rate of infusion sufficient to provide a substantially
7 elevated concentration of the contrast agent in the artery
8 during collection of image data representative of a center of k-
9 space.

1 2. The method of claim 1 wherein the step of
2 administering a magnetic resonance contrast agent further
3 includes temporally correlating a substantially elevated rate of
4 infusion of the contrast agent with the collection of image data
5 representative of the center of k-space according to at least
6 one of a delay time in a delivery system, a location of the
7 artery and a physical condition of the patient.

1 3. The method of claim 1 wherein the step of
2 administering the contrast agent to the patient further includes

3 temporally correlating a maximum rate of infusion of the
4 contrast agent with the collection of image data representative
5 of the center of k-space according to at least one of a delay
6 time in a delivery system, location of the artery and a physical
7 condition of the patient.

1 4. The method of claim 3 wherein the step of
2 administering the contrast agent to the patient further includes
3 administering a paramagnetic contrast agent at a maximum rate of
4 infusion which is greater than 0.0015 Liters/Kg-sec² divided by
5 the relaxivity of the paramagnetic contrast agent.

1 5. The method of claim 1 wherein the step of
2 administering a magnetic resonance contrast agent further
3 includes administering the contrast agent at a substantially
4 elevated rate of infusion about 10 to about 40 seconds before
5 collection of image data representative of the center of k-
6 space.

1 6. The method of claim 1 wherein the step of
2 administering the contrast agent to the patient further includes
3 temporally correlating a period of a substantially elevated rate

4 of infusion with the collection of image data representative of
5 the center of k-space in accordance with a size of the artery so
6 that the concentration of the contrast agent in the artery is
7 substantially greater than veins adjacent to the artery during
8 collection of image data representative of the center of k-
9 space.

1 7. The method of claim 6 wherein the step of
2 administering the contrast agent to the patient further includes
3 administering the contrast agent at an infusion rate and for a
4 period which provides a substantially elevated concentration of
5 the magnetic resonance contrast agent in the artery during more
6 than 50% of the period of collecting image data representative
7 of the center of k-space.

1 8. The method of claim 6 wherein the step of
2 administering the contrast agent to the patient further includes
3 administering the contrast agent at an infusion rate and for a
4 period sufficient to provide an elevated concentration of the
5 magnetic resonance contrast agent in the artery for a period of
6 between about 50% to about 85% of the time of collecting image
7 data representative of the center of k-space.

1 9. The method of claim 6 wherein the step of
2 administering the contrast agent to the patient further includes
3 adapting the timing of a maximum rate of infusion of the
4 contrast agent according to the location of the artery or the
5 physical condition of the patient.

1 10. The method of claim 1 wherein the step of
2 administering the contrast agent to the patient further includes
3 administering a paramagnetic contrast agent having a relaxivity
4 at a rate of infusion sufficient to provide a concentration of
5 the paramagnetic contrast agent in the artery, during collection
6 of image data representative of a center of k-space, of greater
7 than 2.9 sec/relaxivity.

1 11. A method of imaging an artery in a patient using
2 magnetic resonance imaging, comprising,
3 collecting image data; and
4 administering a magnetic resonance contrast agent to the
5 patient while collecting image data, by intravenous infusion, at
6 a rate of infusion sufficient to provide a substantially

7 elevated concentration of the contrast agent in artery relative
8 to adjacent veins during collection of image data corresponding
9 to a center of k-space.

1 12. The method of claim 11 wherein the step of
2 administering a magnetic resonance contrast agent further
3 includes temporally correlating the substantially elevated rate
4 of infusion of the contrast agent with the collection of image
5 data corresponding to the center of k-space in accordance with
6 at least one of a time delay of a delivery apparatus, a location
7 of the artery and a physical condition of the patient.

1 13. The method of claim 11 wherein the step of
2 administering the magnetic resonance contrast agent further
3 includes temporally correlating a maximum rate of infusion with
4 the collection of image data corresponding to the center of k-
5 space in accordance with at least one of a time delay of a
6 delivery apparatus, a location of the artery and a physical
7 condition of the patient.

1 14. The method of claim 11 wherein the step of
2 administering a magnetic resonance contrast agent further

3 includes administering the contrast agent at a substantially
4 elevated rate of infusion about 10 to about 30 seconds before
5 collection of image data corresponding to the center of k-space.

1 15. The method of claim 11 wherein the step of
2 administering a magnetic resonance contrast agent further
3 includes administering the contrast agent at a maximum rate of
4 infusion about 10 to about 40 seconds before collection of image
5 data corresponding to the center of k-space.

1 16. The method of claim 11 wherein the step of
2 administering the contrast agent to the patient further includes
3 temporally correlating a period of a substantially elevated rate
4 of infusion of the contrast agent to the collection of image
5 data corresponding to the center of k-space in accordance with
6 a size of the artery so that the concentration of the contrast
7 agent in the artery is substantially greater than adjacent veins
8 during collection of image data corresponding to the center of
9 k-space.

1 17. The method of claim 16 wherein the step of
2 administering the contrast agent to the patient further includes

3 administering the contrast agent for a period sufficient to
4 provide a substantially elevated concentration of the magnetic
5 resonance contrast agent in the artery for at least 50% of the
6 period of collecting image data corresponding to the center of
7 k-space.

1 18. The method of claim 11 wherein the step of
2 administering the contrast agent to the patient further includes
3 adapting the timing of a maximum rate of infusion of the
4 contrast agent according to a location of the artery.

1 19. The method of claim 11 wherein the step of
2 administering a magnetic resonance contrast agent includes
3 administering the contrast using a mechanical injector which is
4 spring-loaded, pneumatic powered, or electrically powered.

1 20. The method of claim 11 wherein the step of
2 administering a magnetic resonance contrast agent includes
3 administering the contrast agent using a mechanical injector
4 wherein the mechanical injector includes a non-magnetic spring
5 to pressurize the contrast agent for infusion into the patient.

1 21. The method of claim 11 wherein the step of
2 administering a magnetic resonance contrast agent includes
3 administering a gadolinium chelate using a mechanical injector
4 which is adapted to receive a vessel containing the gadolinium
5 chelate wherein the mechanical injector includes a non-magnetic
6 spring.

1 22. The method of claim 11 wherein the step of
2 administering the contrast agent to the patient further includes
3 administering a paramagnetic contrast agent having a relaxivity
4 at a rate of infusion sufficient to provide a concentration of
5 the paramagnetic contrast agent in the artery, during collection
6 of image data corresponding to a center of k-space, of greater
7 than 2.9 sec^{-1} relaxivity $^{-1}$.

1 23. A method of imaging an artery in a patient using a
2 gadolinium chelate, comprising,
3 collecting image data; and
4 administering the gadolinium chelate to the patient, by
5 intravenous infusion, at a rate of infusion for providing a

6 maximum concentration of the gadolinium chelate in an artery
7 relative to adjacent veins during collection of image data
8 corresponding to a center of k-space.

1 24. The method of claim 23 wherein the step of
2 administering the gadolinium chelate further includes
3 administering the gadolinium chelate at a maximum rate of
4 infusion which is greater than 0.0015 Liters/Kg-sec² divided by
5 the relaxivity of the gadolinium chelate.

1 25. The method of claim 23 wherein the step of
2 administering the gadolinium chelate to the patient further
3 includes administering a maximum rate of infusion of the
4 gadolinium chelate about 10 to about 40 seconds before
1 collecting image data corresponding to the center of k-space.

1 26. The method of claim 23 wherein the step of
2 administering the gadolinium chelate further includes temporally
3 correlating a maximum rate of infusion of the gadolinium chelate
4 with the mapping of k-space in accordance with a delay time in
5 a delivery system, a location of the artery or a physical
6 condition of the patient.

1 27. The method of claim 23 wherein the step of
2 administering the gadolinium chelate to the patient further
3 includes temporally correlating a period of the maximum
4 concentration of the gadolinium chelate to the collection of
5 image data corresponding to the center of k-space in accordance
6 with a size of the artery.

1 28. A method for administering a magnetic resonance
2 contrast agent into a vein of a patient to enhance a magnetic
3 resonance image of an artery of the patient, the method
4 including:

5 collecting image data; and
6 administering the contrast agent into the vein at an
7 infusion rate and for a period of time sufficient to provide a
8 maximum concentration of the contrast agent in the artery during
9 collection of at least a portion of the image data which
10 corresponds to a center of k-space.

1 29. The method of claim 28 wherein the step of
2 administering a magnetic resonance contrast agent further
3 includes temporally correlating a maximum rate of infusion of

4 the contrast agent with the mapping of k-space in accordance
5 with a delay time in a delivery system, a location of the artery
6 or a physical condition of the patient.

1 30. The method of claim 28 wherein the step of
2 administering the contrast agent to the patient further includes
3 administering a paramagnetic contrast agent at a maximum rate of
4 infusion which is greater than 0.0015 Liters/Kg-sec² divided by
5 the relaxivity of the contrast agent.

1 31. The method of claim 28 wherein the step of
2 administering the contrast agent to the patient further includes
3 temporally correlating a period of an elevated rate of infusion
4 of the contrast agent with the mapping of k-space in accordance
5 with a size of the artery so that the concentration of the
6 contrast agent in the artery is substantially greater than
7 adjacent veins while collecting image data corresponding to the
8 center of k-space.

1 32. The method of claim 31 wherein the step of
2 administering the contrast agent to the patient further includes
3 administering the contrast agent at an infusion rate which

4 provides a substantially elevated concentration of the magnetic
5 resonance contrast agent in the artery relative to adjacent
6 veins for at least 50% of the time of the step of collecting
7 image data corresponding to the center of k-space.

1 33. The method of claim 28 wherein the step of
2 administering a magnetic resonance contrast agent includes
3 administering the contrast agent using a mechanical injector
4 which is spring-loaded, pneumatic powered, or electrically
5 powered.

1 34. The method of claim 28 wherein the step of
2 administering a magnetic resonance contrast agent includes
3 administering a gadolinium chelate using a mechanical injector
4 which is adapted to receive a vessel containing the gadolinium
5 chelate wherein the mechanical injector includes a non-magnetic
6 spring to pressurize the contrast for infusion into the patient.

1 35. The method of claim 34 wherein the step of
2 administering the contrast agent to the patient further includes
3 administering gadolinium chelate at a maximum rate of infusion

4 which is greater than 0.0015 Liters/Kg-sec² divided by the
5 relaxivity of the contrast agent.

1 36. A magnetic resonance compatible apparatus for
2 administering a magnetic resonance contrast agent into a vein of
3 a patient to enhance a magnetic resonance image of an artery of
4 the patient, the apparatus comprises:

5 a spring-powered device, including a non-magnetic spring,
6 for administering the contrast agent into the vein at an
7 infusion rate and for a period of time sufficient to provide a
8 substantially elevated concentration of the contrast agent in
9 the artery during collection of at least a portion of the image
10 data which corresponds to a center of k-space.

1 37. The apparatus of claim 36 wherein the magnetic
2 resonance contrast agent is contained in a syringe having an
3 orifice at a distal end and a plunger for engaging the contrast
4 agent, the syringe being coupled to the spring-powered device
5 such that the spring-powered device engages the plunger to
6 administer the contrast agent at an infusion rate in the range
7 of about 4 ml/minute to about 600 ml/minute.

1 38. The apparatus of claim 36 further including a rate
2 adjustment mechanism coupled to the plunger of the syringe to
3 adjust the infusion rate of the contrast agent.

1 39. The apparatus of claim 36 further including a fluid
2 flow restrictor coupled to the orifice of the syringe to
3 control, in combination with the non-magnetic spring, the
4 infusion rate of the contrast agent.

1 40. The apparatus of claim 39 wherein the fluid flow
2 restrictor is a needle, a precision orifice, or tubing having a
3 narrow calibre.

1 41. The apparatus of claim 39 further including a rate
2 adjustment means for adjusting the infusion rate of the contrast
3 agent.

1 42. The apparatus of claim 36 further including a flow
2 rate indicator to visually or audibly indicate the infusion rate
3 of the contrast agent.

1 43. The apparatus of claim 36 wherein the non-magnetic
2 spring is comprised of eljaloy or inconel.

1 44. The apparatus of claim 36 wherein the spring-powered
2 device administers a paramagnetic contrast agent having a
3 relaxivity at a rate of infusion sufficient to provide a
4 concentration of the paramagnetic contrast agent in the artery
5 of greater than 2.9 sec^{-1} relaxivity¹ during collection of a
6 portion of the image data which corresponds to a center of k-
7 space.

1 45. An apparatus for administering a magnetic resonance
2 contrast agent into a vein of a patient to enhance a magnetic
3 resonance image of an artery of the patient, the apparatus
4 comprises:

5 an infusion mechanism, including infusion means for
6 matching an infusion rate with a mapping of at least a portion
7 of k-space and for infusing the contrast agent at a rate and a
8 duration sufficient to provide a maximum concentration of the
9 contrast agent in the artery during collection of at least a
10 portion of image data which corresponds to a center of k-space.

1 46. The apparatus of claim 45 wherein the administration
2 means is a mechanical injector which is spring-loaded, pneumatic
3 powered, or electrically powered.

1 47. The apparatus of claim 46 wherein the administration
2 means is coupled to a container having the magnetic resonance
3 contrast agent contained therein.

1 48. The apparatus of claim 47 wherein the container
2 includes an orifice and wherein the apparatus further includes
3 a fluid flow restrictor coupled to the orifice.

1 49. The apparatus of claim 48 wherein the fluid flow
2 restrictor is a needle, a precision orifice, or tubing having a
3 narrow calibre.

1 50. The apparatus of claim 45 further including a rate
2 adjustment means for adjusting the infusion rate of the contrast
3 agent to the patient.

1 51. The apparatus of claim 45 further including a flow
2 rate indicator to visually or audibly indicate the infusion rate
3 of the contrast agent.

1 52. An apparatus for injecting a magnetic resonance
2 contrast agent into a patient, comprising,
3 an injection mechanism to match a substantially elevated
4 contrast agent concentration in the artery relative to the
5 adjacent veins with a mapping of k-space by controlling the rate
6 of injection of the contrast agent such that a substantially
7 elevated rate of injection correlates with the collection of
8 image data corresponding to a center of k-space.

1 53. The apparatus of claim 52 wherein the injection
2 mechanism temporally correlates the substantially elevated rate
3 of injection with the collection of image data corresponding to
4 the center of k-space in accordance with a location of the
5 artery.

1 54. The apparatus of claim 52 wherein the injection
2 mechanism temporally correlates a maximum rate of injection of
3 the contrast agent with the collection of image data

4 corresponding to the center of k-space in accordance with a
5 location of the artery.

1 55. The apparatus of claim 52 wherein the injection
2 mechanism provides a substantially elevated rate of injection of
3 the contrast agent about 10 to about 40 seconds before
4 collecting image data which corresponds to the center of k-
5 space.

1 56. The apparatus of claim 52 wherein the injection
2 mechanism provides a maximum rate of injection of the contrast
3 agent about 10 to about 30 seconds before collecting image data
4 which corresponds to the center of k-space.

1 57. The apparatus of claim 52 wherein the injection
2 mechanism temporally correlates a period of a substantially
3 elevated rate of injection of the contrast agent with the
4 collection of image data corresponding to the center of k-space
5 in accordance with a size of the artery so that the
6 concentration of the contrast agent in the artery is
7 substantially greater than adjacent veins while collecting image
8 data which corresponds to the center of k-space.

1 58. The apparatus of claim 57 wherein injection mechanism
2 injects the contrast agent into the patient at a rate and
3 duration of injection which provides a substantially elevated
4 concentration of the magnetic resonance contrast agent in the
5 artery for at least 50% of the time of collecting image data
6 corresponding to the center of k-space.

1 59. The apparatus of claim 52 wherein the injection
2 mechanism injects a paramagnetic contrast agent having a
3 relaxivity at a rate of injection sufficient to provide a
4 concentration of the paramagnetic contrast agent in the artery,
5 during collection of image data representative of a center of k-
6 space, of greater than 2.9 sec^{-1} relaxivity $^{-1}$.